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A Comparative Study of Oxygen Transfer Over Contracted and Uncontracted Weirs

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Introduction

- Aeration is a process that introduces air into the water, thereby increasing its dissolved oxygen content.
- The dissolved oxygen concentration is a key indicator of water quality, and a minimum of 4 ppm is essential for maintaining a healthy aquatic ecosystem.
- The water released from hydroelectric power plants usually has very low dissolved oxygen concentration, so aeration becomes necessary.
- In today's scenario, water bodies like rivers and lakes are often polluted, and aeration can play a rejuvenating role in restoring their health.
- The aeration process involves creating turbulence in the water, which can be achieved through hydraulic structures like weirs.
- These structures generate turbulence when water plunges over them and strikes the pool below, effectively carrying air into the pool, thereby increasing dissolved oxygen levels.

Methodology

- The storage tank was filled with tap water and deoxygenated to 1 to 2 ppm by adding a calculated amount of sodium sulphite (Na_2So_3) and cobaltous chloride ($CoCl_2.6H_2O$) as catalyst (Tiwari et al., 2023).
- The disolvoe oxygen was measured using HACH DO meter.
- The air concentration was measured using phase detection probe.

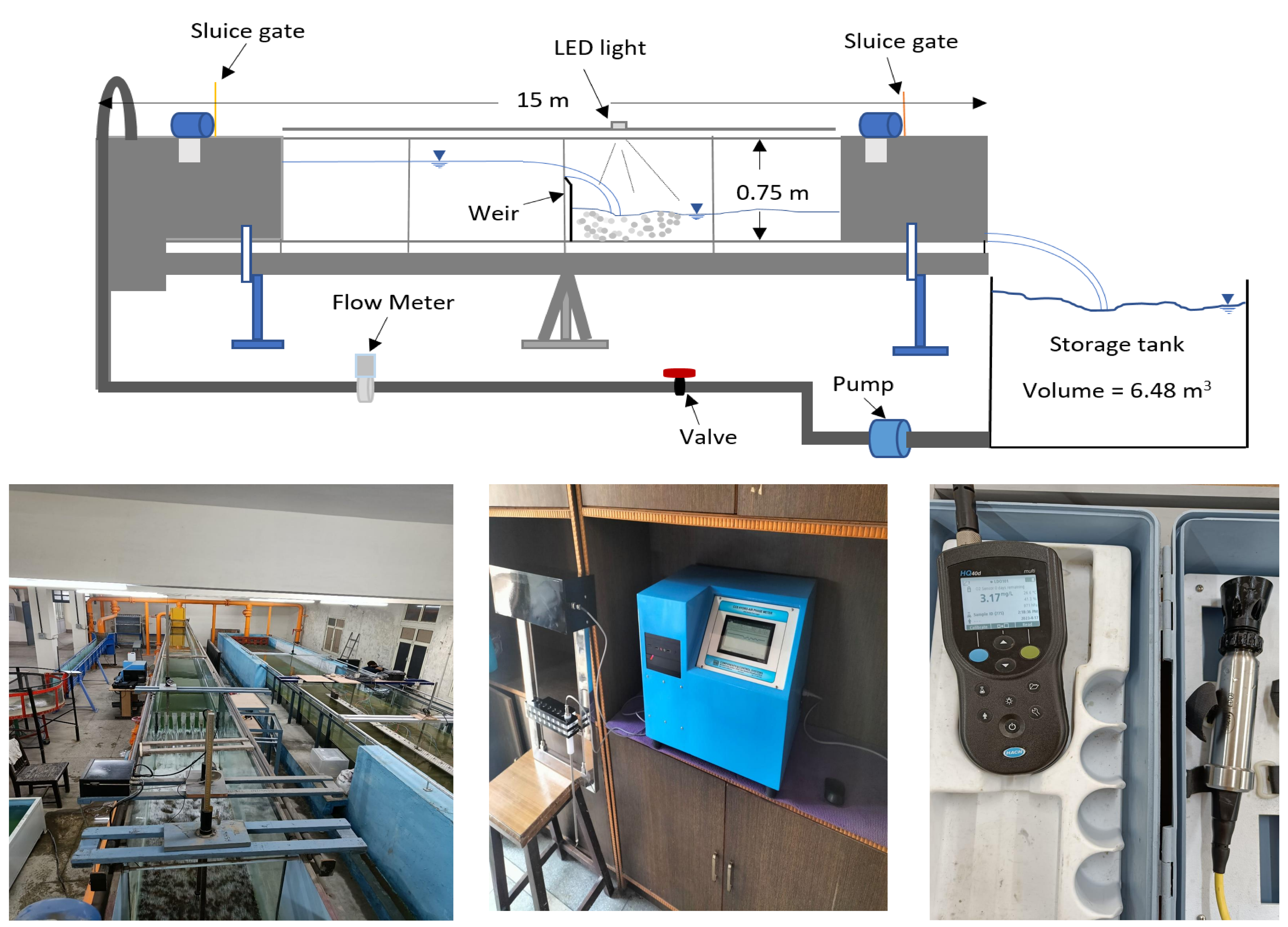

Fig. 1: Experimental setup and instruments

Governing Equation

- Fick's law describes the mass transfer rate, and the mass transfer of volatile gas like oxygen from air to water can be expressed as:

$$\frac{dc}{dt} = -K_l a\,(C_s - C) \quad [1]$$

Initial Condition

At t = 0, C = C_u

integrating Eq. (1) from time t=0 to t=t, one gets:

$$\int_{C_u}^{C_d} \frac{dc}{C_s - C} = -K_l a \int_0^t dt \quad [2]$$

$$\ln\frac{C_s - C_d}{C_s - C_u} = -K_l at \quad [3]$$

$$C_t = C_s - (C_s - C_o)e^{-K_L at} \quad [4]$$

$$r = \frac{(C_s - C_d)}{(C_s - C_u)} = exp\,(K_L at) \quad [5]$$

$$E = 1 - \frac{1}{r} \quad [6]$$

$$E = \frac{(C_d - C_u)}{(C_s - C_u)} \quad [7]$$

$$1 - E_{20} = (1 - E)^{1/f} \quad [8]$$

$$f = 1 + 0.02103\,(T-20) + 8.261 \times 10^{-5}\,(T - 20)^2 \quad [9]$$

Eq. (8) can be used to calculate the aeration efficiency at standard temperature of 20 ℃.

C_s= saturation concentration
C_d = D/S concentration
C_u = U/S concentration
K_L= liquid film coefficient
a = specific interface area
E = aeration efficiency at any temperature T
E_{20}= aeration efficiency at standard temperature 20 ℃
f = temperature correction factor

Results

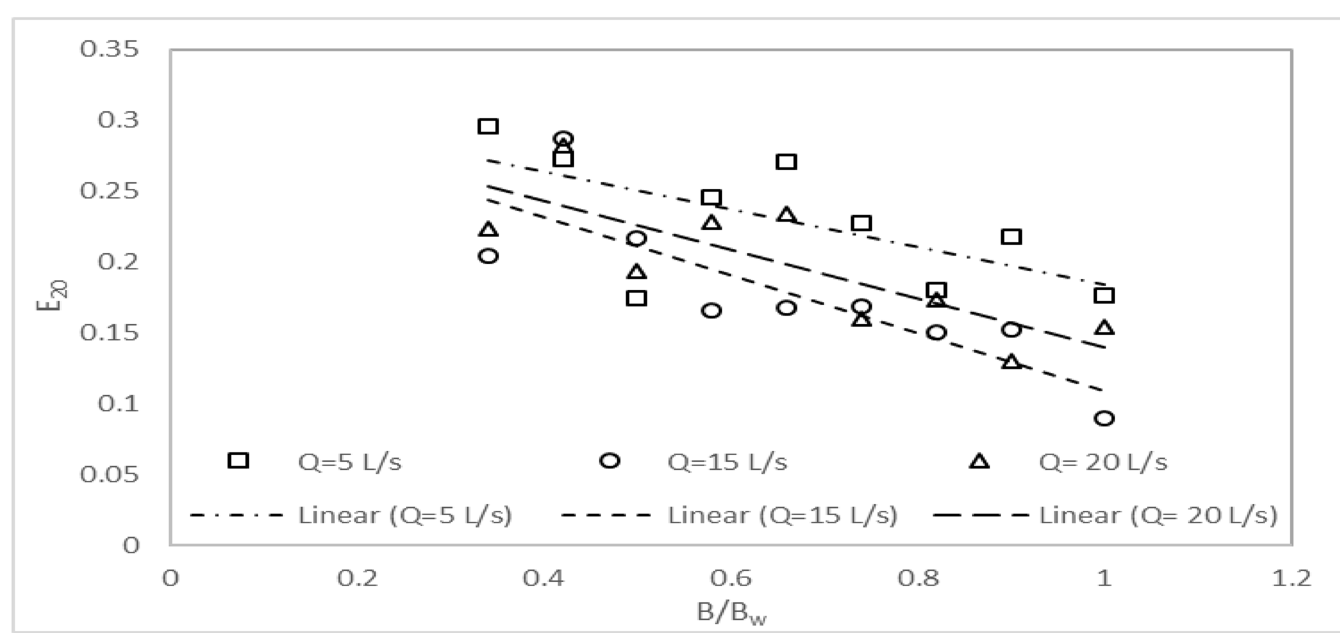

Fig. 2: Variation of aeration efficiency with width contraction

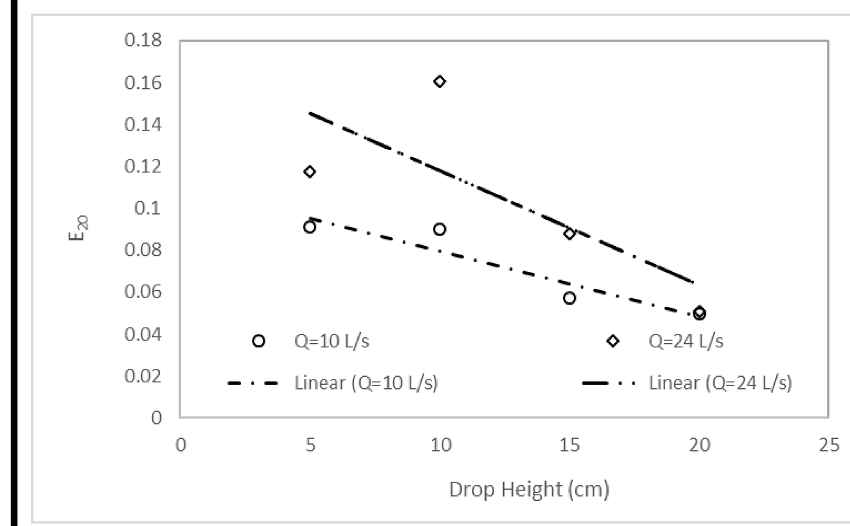

Fig. 3: E_{20} V/s Drop height

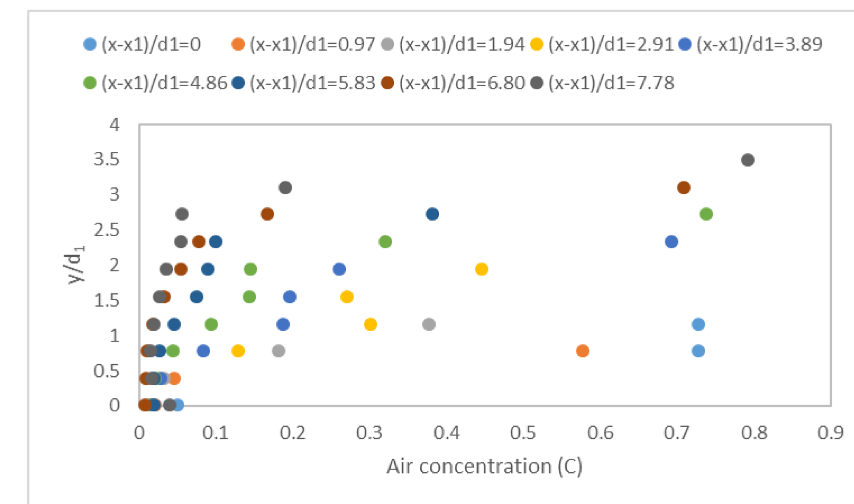

Fig. 4: Air concentration profile

- Fig.2 shows the variation of aeration efficiency with jet width of weir where B is actual width of jet and B_w is the total width of weir
- The aeration efficiency increases with splitting of jet because of jet interaction and better mixing.
- Fig.3 shows the variation of aeration efficiency with drop height, the aeration efficiency is more for heigh drop height because the mlore is the height more is the impact velocity.
- Fig. 4 shows the air concentration profile of a jump which forms when jet from weir attains normal depth resulting in high air entrainment and oxygen transfer.

Conclusions

- The aeration efficiency of contracted weir is more than uncontracyted.
- The aeration efficiency decreases with increase in flow rate.
- The aeration efficiency increases with increase in drop height.
- Significant air entrainment was observed near the jump toe.
- The mean air concentration was also found to be higher at jump toe.
- The maximum air concentration decreased with increase in distance from entrapment point.

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